CSE 390B, Winter 2023

Building Academic Success Through Bottom-Up Computing

Time Management & Boolean Arithmetic

Time Management, Overview of Numbers in Binary, Boolean Arithmetic, Circuits for Adding Binary Numbers

Connect With Your CSE 390B Peers

- Download Discord from https://discord.com/download
- Log in or create an account
- Click on  icon in left-most column to create channel
  - Select “Create My Own”
  - Select “For me and my friends”
  - Give your server a name! (e.g., “CSE 390B 23wi”)
- Use the 

button to invite peers
- Create some text and voice channels. Some ideas:
  - Text: #projects, #questions, #chill, #random
  - Voice: 🔊 Study Room, 🔊 Lounge
- Feel free to connect via Slack, Messenger, etc. too

Project 2 Check-in

- How has Project 2 been coming along?
- What questions do you have about Project 2?
- Following the plan of action outlined in slide 34 of last Thursday's lecture will work for implementing most chips
- Remember to double check your submission on GitLab
  - Navigate to GitLab, open tags, and verify that the associated commit includes your expected changes

Lecture Outline

- **Time Management**
  - **Identifying Weekly Time Commitments**
- Overview of Numbers in Binary
  - Comparison Between Binary and Decimal
- Boolean Arithmetic
  - Addition Operator and Handling Binary Overflow
- Circuits for Adding Binary Numbers
  - Overview of the Half Adder and Full Adder

Time Management

- One of your most valuable resources in college is time

- What typically fills up your time during the quarter?
  - Lectures, quiz sections, and attending office hours
  - Part-time jobs and working
  - Studying
  - Extracurricular activities or RSOs
  - Commuting
  - Chores at home
  - Socializing with friends and family
  - Physical, mental, spiritual activities

Weekly Time Commitments

- Class meeting times and quiz sections
- Family, friends, community, extracurricular commitments
- Physical, mental, social, spiritual activities
- Studying for each of your classes
  - The number of credits for a course reflects the number of hours the class meets
  - In general, courses require two hours of homework for every one hour of class
- What else is not reflected given your specific situation?

Tracking Weekly Time Commitments

- We often don't realize what takes up our time until we manually track how we use our time
- Exercise: Complete the weekly time commitments table
- Tip: Use different colors for different activity types

Weekly Time Commitments Table Name: _____

Time	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
7:30am							
8:00am							
8:30am							
9:00am							
9:30am							
10:00am							
10:30am							
11:00am							
11:30am							
12:00pm							
12:30pm							
1:00pm							
1:30pm							
2:00pm							
2:30pm							
3:00pm							
3:30pm							
4:00pm							
4:30pm							
5:00pm							
5:30pm							
6:00pm							
6:30pm							
7:00pm							
7:30pm							
8:00pm							
8:30pm							
9:00pm							
9:30pm							
10:00pm							
10:30pm							
11:00pm							
11:30pm							

Time Management Group Discussion

Now that you've filled out your weekly time commitments, discuss the following in groups for 4-6 minutes:

- Does anything surprise you about the way you spend your time?
- What might you change about the way you utilize your time?
- How could you use this time commitments sheet in the future?

Lecture Outline

- Time Management
  - Identifying Weekly Time Commitments
- **Overview of Numbers in Binary**
  - **Comparison Between Binary and Decimal**
- Boolean Arithmetic
  - Addition Operator and Handling Binary Overflow
- Circuits for Adding Binary Numbers
  - Overview of the Half Adder and Full Adder

What is Binary?

- A **base n** number system is a system of number representation with n **symbols**

- Decimal system is a **base 10** number system
  - Base 10 symbols: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 (each called a **digit**)
  - Increase a number by moving to the next greatest symbol
  - Add another digit when we run out of symbols

- Binary is a **base 2** number system
  - Base 2 symbols: 0, 1 (each called a **bit**)
  - Often prefixed with 0b (e.g., $0\text{b}1101$, $0\text{b}10$)
  - **Least-significant bit (LSB):** Lowest-order position of a binary value
  - **Most-significant bit (MSB):** Highest-order position of a binary value

Representing Numbers in Base 2

- Binary numbers are identical, except in base 2
  - Describe a value by specifying multiples of powers of 2
  - For example, a breakdown of $0b1101$ in binary (13 in decimal)

Binary	Power of 2
$0b1000$	1×2^3
$0b0100$	1×2^2
$0b0000$	0×2^1
$0b0001$	1×2^0

Binary vs. Decimal

Binary	Decimal
0b000	0
0b001	1
0b010	2
0b011	3
0b100	4
0b101	5
0b110	6
0b111	7
…	…

Lecture 3: Time Management & Boolean Arithmetic

When poll is active, respond at **PollEv.com/cse390b**

What is the binary representation of the decimal value of 29?

- 0b011011
- 0b011101
- 0b100011
- 0b100111
- We're lost…

Total Results: 0

Powered by Poll Everywhere

Lecture Outline

- Time Management
  - Identifying Weekly Time Commitments
- Overview of Numbers in Binary
  - Comparison Between Binary and Decimal
- **Boolean Arithmetic**
  - **Addition Operator and Handling Binary Overflow**
- Circuits for Adding Binary Numbers
  - Overview of the Half Adder and Full Adder

Roadmap: Boolean Arithmetic

- Addition — Implement
- Subtraction — Get it for free!
- Comparison (<, >, ==, !=) — Get it for free!
- Multiplication — Postpone to software
- Division — Postpone to software

Binary Addition

- How do we add two binary numbers?
  - As humans, we could convert to decimal and then back

- Example: $0\text{b}101 + 0\text{b}010$
  - First convert $0\text{b}101$ to decimal (result is 5)
  - Next convert $0\text{b}010$ to decimal (result is 2)
  - Add the decimal numbers and convert back to binary
    - $5 + 2 = 7$, which is $0\text{b}111$ in binary

- What's more useful is understanding the rules of binary addition so we can teach them to a computer

Case Study: Decimal Addition

- Consider how we perform decimal addition
  - Right to left (least significant place to most significant place)
  - When a column's result is more than one digit, carry over the digit that overflows

- Example:

carry				
a	5	7	8	3
b	2	4	5	6
sum				

Binary Addition

- Binary addition conceptually the same as decimal addition
  - Right to left (least significant place to most significant place)
  - When a column's result is more than one digit, carry over the bit that overflows

- Example:

carry				
a	0	1	1	1
b	0	1	0	1
sum				

Binary Overflow

- What if there's a carry bit in the last column?

- Example:

carry				
a	0	1	1	0
b	1	0	1	0
sum				

Binary Overflow

- What if there's a carry bit in the last column?

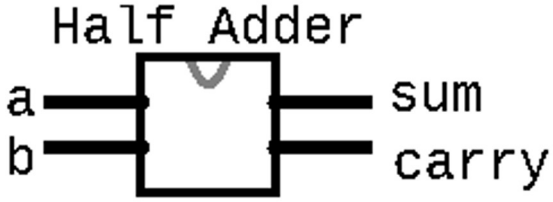
- We can't represent it in our fixed-width numbers
  - We are going to "drop" or ignore the extra carry bit

carry					
a		0	1	1	0
b		1	0	1	0
sum					

Lecture Outline

- Time Management
  - Identifying Weekly Time Commitments
- Overview of Numbers in Binary
  - Comparison Between Binary and Decimal
- Boolean Arithmetic
  - Addition Operator and Handling Binary Overflow
- **Circuits for Adding Binary Numbers**
  - **Overview of the Half Adder and Full Adder**

Half Adder



- Circuit for adding two bits together
- Takes in two inputs: `a`, `b`
  - `a` is the first bit being added
  - `b` is the corresponding bit to be added
- Produces two outputs: `sum`, `carry`
  - `sum` is the value to be put for this column in the result
  - `carry` is the value to be carried over to the next column

carry				
a	0	1	1	0
b	1	0	1	0
sum				

```
/**
 * Computes the sum of 2 bits
 */

CHIP HalfAdder {
    IN a, b;
    OUT sum, carry;

    PARTS:
    // Put your code here:

}
```

Half Adder Example

- Example: $0b0111 + 0b0101$

- For the right-most (least significant) column:
  - $a = 1$
  - $b = 1$
  - sum =
  - carry =

carry				
a	0	1	1	1
b	0	1	0	1
sum				

Half Adder Example

- Boolean expressions:
  - sum =
  - carry =

a	b	sum	carry
0	0		
0	1		
1	0		
1	1		

Half Adder Group Work

- Determine the half adder logical Boolean expression
  - First, fill in the truth table values for sum and carry based on the inputs
  - Then, develop a Boolean expression for sum and carry based on the truth table

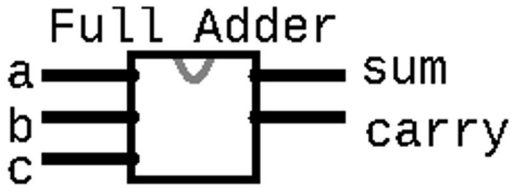
- Five-minute group discussion, identify one person to share each of the following as a large group:
  - Overview of what the half adder does
  - Thought process for reaching the Boolean expression for sum
  - Thought process for reaching the Boolean expression for carry

Half Adder Example

- Boolean expressions:
  - sum = a XOR b
  - carry = a AND b

a	b	sum	carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Full Adder



- Circuit for adding three bits together (two bits *and* carry bit together from previous column)
  - `a` is the first bit being added
  - `b` is the corresponding bit to be added
  - `c` is the carry bit from the right column

carry				
a	0	1	1	0
b	1	0	1	0
sum				

- Produces two outputs: `sum`, `carry`
  - `sum` is the value to be put for this column in the result
  - `carry` is the value to be carried over to the next column

```
/**
 * Computes the sum of 3 bits
 */

CHIP FullAdder {
    IN a, b, c;
    OUT sum, carry;

    PARTS:
    // Put your code here:

}
```

Full Adder

- Example: 0b0111 + 0b0101

- For the second (second least significant) column:
  - a = 1
  - b = 0
  - c = 1
  - sum =
  - carry =

carry			1	
a	0	1	1	1
b	0	1	0	1
sum				0

Full Adder Truth Table

a	b	c	sum	carry
0	0	0		
0	0	1		
0	1	0		
0	1	1		
1	0	0		
1	0	1		
1	1	0		
1	1	1		

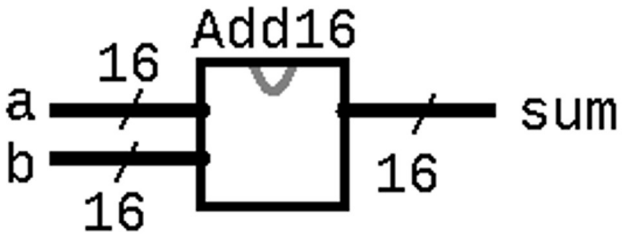
Lecture 3: Time Management & Boolean Arithmetic

Loading...

Full Adder Truth Table

a	b	c	sum	carry
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Multi-Bit Adder



- Adds two 16-bit numbers

- Connects the full adders for each column together (wires the out carry from one column to the in carry of the next)

```
/**
 * Adds two 16-bit Two's Complement
 * values. Overflow is ignored.
 */
CHIP Add16 {
  IN a[16], b[16];
  OUT sum[16];

  PARTS:
  // Put your code here:

}
```

```
    … 0 1 1 1 0 0
    … 0 0 1 0 1 0 1
+   … 1 0 1 1 1 0 0
-------------------
    … 1 1 1 0 0 0 1
```

Lecture 3 Reminders

- **Project 2 due Thursday (1/12) at 11:59pm**

- Course Staff Support
  - Eric has office hours in CSE2 153 today after lecture
  - Feel free to post your questions on the Ed discussion board too